Appendix D

Report on Treatability Studies for the Solar Ponds Plume

Final Report

Treatability Studies for Solar Ponds Plume at Rocky Flats

Prepared for

John Boylan
S.M. Stoller Corporation

By

Dave Gilbert, Mitch Olson and Tom Sale
The Center for Contaminant Hydrology
Department of Civil Engineering
Colorado State University
Fort Collins, CO

April 2007

Introduction

This report has been prepared to summarize the findings of the Treatability Studies for the Solar Ponds Plume at the Rocky Flats Site conducted by Colorado State University (CSU) in the fall of 2006. The primary concern with the Solar Ponds Plume is high concentrations of nitrate and uranium in groundwater and limited efficacy of the existing groundwater treatment system. The treatability study was conducted to evaluate selected treatments to facilitate biological reduction of nitrate. Removal of uranium was not required for these studies.

Treatability Study Objectives

The primary objective of the treatability study was to provide data that could be used to (1) evaluate use of ethanol as a carbon source and (2) compare two types of supporting media. For this study, the supporting media included pea gravel and Jaeger Environmental Nor Pac polypropylene media. The experimental design is shown in Table 1. The four test reactors consisted of 10 cm ID plexiglass columns. Two columns were prepared with each media type – one with ethanol added and one without. For each media type, a column length was selected to achieve similar pore volumes in all columns in the study. All of the columns were inoculated with activated sludge collected from the City of Fort Collins Drake Wastewater Treatment Plant. The sludge had been shown to contain nitrate reducing consortium of microorganisms. A schematic illustration of the experimental setup is shown in Figure 1. Site water was pumped into a holding tank from the SPPTS Cell 1 distribution gallery using a downhole diaphragm pump (manufactured by KNF Neuberger). Site water from the holding tank was delivered to the columns by a four channel peristaltic pump (manufactured by Ismatec, Inc). Absolute ethanol (200 proof) was delivered to the test columns using a low flow peristaltic pump (manufactured by Ismatec, Inc.).

The columns were submersed in a water bath throughout the study. The objectives of the water bath included (1) maintaining an anaerobic environment in the columns by preventing oxygen entry and (2) controlling column temperatures. The downhole pump provided more water than was required for the reactors. The excess water was circulated through the bath with the intention of maintaining temperatures near those encountered *in situ.*

Effluent from each column was collected and the volume monitored to ensure that each column was receiving comparable throughput. Effluent was also analyzed for nitrate concentration (Hach colorimetric method), temperature, specific conductivity, pH, dissolved oxygen, and oxidation-reduction potential (system manufactured by YSI, model no 610).

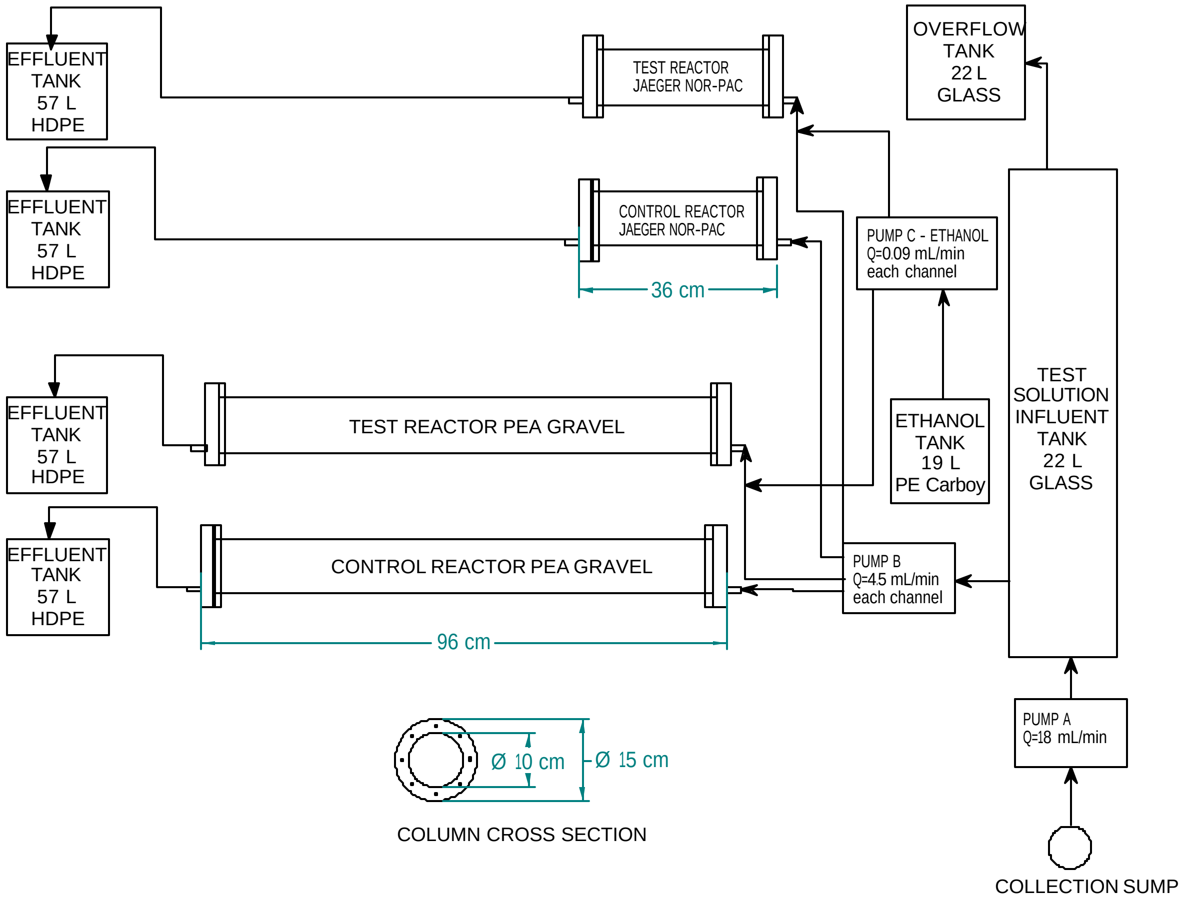

Figure 1. Schematic of treatability study setup.

Table 1: Experimental Design

Reactor	Media	Porosity	Ethanol	Reactor volume (L)	Approximate media surface area (ft^2)
1	Pea Gravel	0.3	none (control)	7.4	7
2	Pea Gravel	0.3	2% by vol	7.4	7
3	Jaeger Environmental Nor Pac (Polypropylene)	0.87	none (control)	2.4	9
4	Jaeger Environmental Nor Pac (Polypropylene)	0.87	2% by vol	2.4	9

Results

Results from the treatability testing are discussed in this section.

Nitrate removal – During the course of the testing, no significant nitrate removal was observed (Figure 2). Influent nitrate concentrations varied between approximately 200 to over 300 mg/L as N. Although temperature conditions (Figure 3) appeared to be favorable for microbial growth and nitrate reduction, a closer examination of daily variation in temperature (Figure 4) suggests that temperature conditions varied significantly over a 24 hour period and may not have allowed for significant microbial growth.

Specific Conductivity and Dissolved Oxygen – Measured specific conductivity values generally increased throughout the test. This data supports the conclusion that nitrate was not reduced to N_2 gas (Figure 5). The expected decrease in dissolved oxygen associated with establishment of reducing conditions was also not observed (Figure 6).

pH and Oxidation/Reduction Potential – A minor decrease in pH was observed over the course of the testing (Figure 7). This result is consistent with a lack of development of reducing conditions that would be necessary for nitrate reduction (i.e., oxidizing conditions were present in all columns for the duration of the testing). Although oxidation of ethanol may result in a decrease in pH (increasing the partial pressure of CO_2), the reduction of nitrate to either $N_{2(g)}$ or NH_4^+ would result in a pH increase. The decrease in pH observed may therefore be associated with the oxidation of ethanol without the reduction of nitrate. Oxidation/reduction potentials (ORP) are shown in Figure 8. Significant fluctuations in ORP are noted throughout the experiment. A steady decline in ORP that would indicate establishment of anaerobic denitrifying bacteria is not apparent.

Following several weeks of no apparent nitrate removal, a visible dye tracer test was conducted to evaluate the as-built hydraulic retention time in each test reactor. Results from the tracer test indicated initial breakthrough of tracer in the NorPac control reactor (t~10 minutes) and the NorPac test reactor (~90 minutes) was significantly shorter than the calculated retention time (8 hr). Initial breakthrough in the pea gravel reactors (control ~ 175 minutes and test reactor ~120 minutes) was also significantly shorter than the calculated hydraulic retention time. From these results, the decision was made to change the operation of the reactors to a pulsed mode in which influent water was pumped through the reactor for 16 hours/day and the reactors were held stagnant for 8 hr/day after which the effluent was sampled for nitrate removal. Unfortunately, cold temperatures led to severe icing and failure of the experiment approximately 2 weeks later. Data collected regarding the pulsed mode of operation were inconclusive.

An informal lab study was conducted to evaluate if the proper nitrate reducing consortium of microbes was present in the inoculum used in the treatability study. The study consisted of five 250 mL amber glass reaction vessels into which site water was introduced. Treatments included inoculum only, inoculum + ethanol, inoculum + ethanol + corn syrup, inoculum + ethanol + corn syrup + yeast extract and, addition of the supernatant from the inoculum + ethanol + corn syrup. Results suggested that the inoculum used contained nitrate reducing microbes. Differences between reactors were primarily the rate at which the nitrate was reduced. The reactor testing the supernatant was not effective at reducing nitrate suggesting that the microbes necessary reside in the floc.

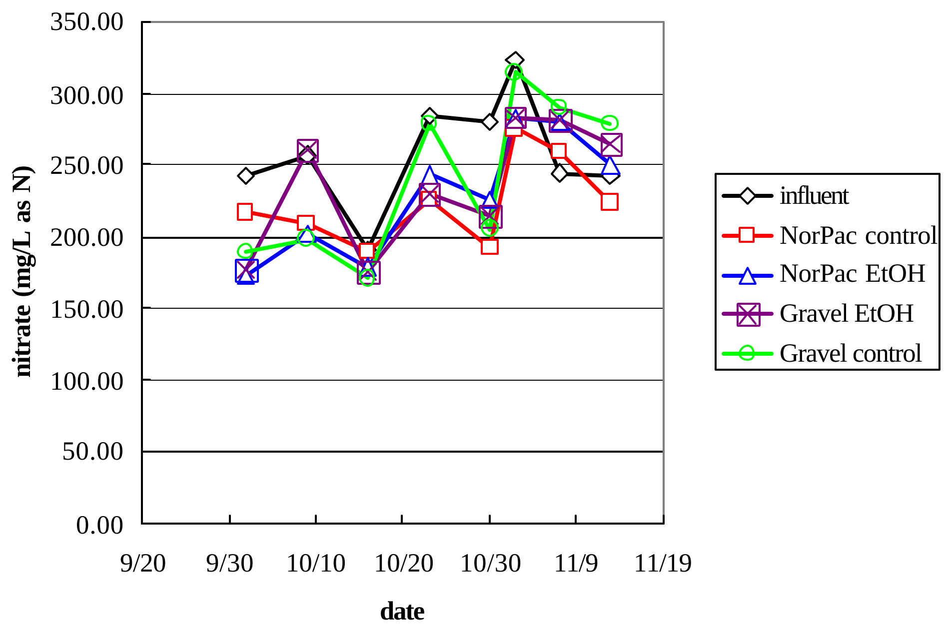

Figure 2. Nitrate concentration measured in the influent and effluent from each reactor over time during the treatability study.

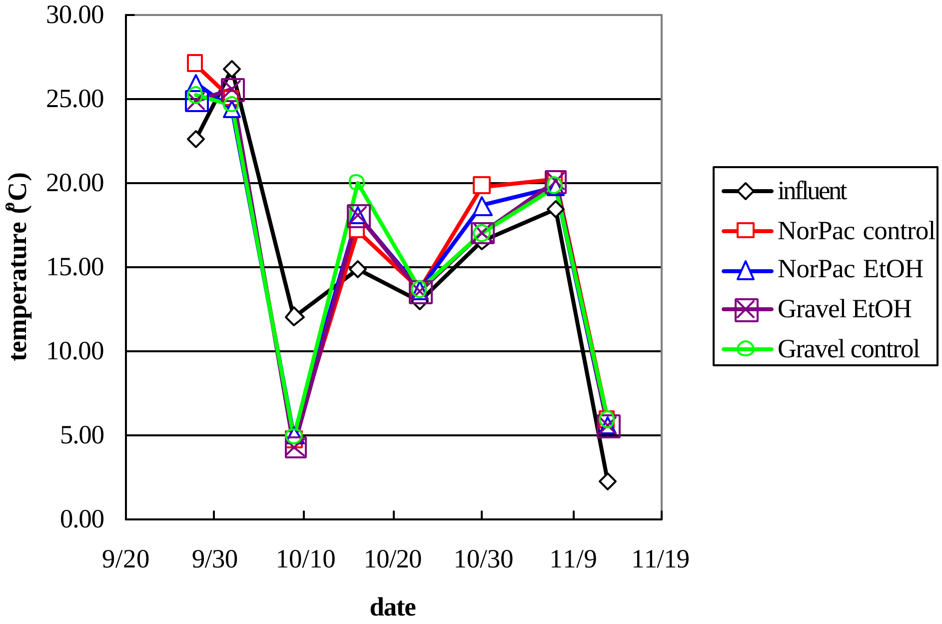

Figure 3. Temperature measured in the influent and effluent from each reactor over time during the treatability study.

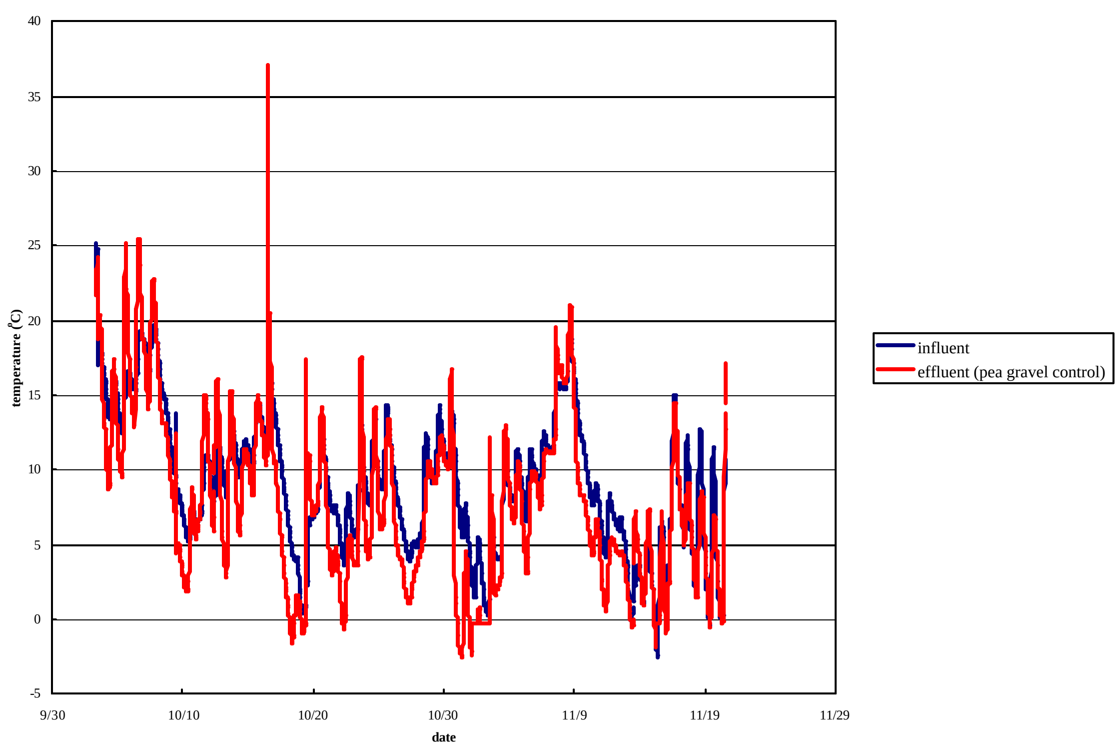

Figure 4. Daily temperature variability measured in the influent water and the effluent from the pea gravel control reactor .

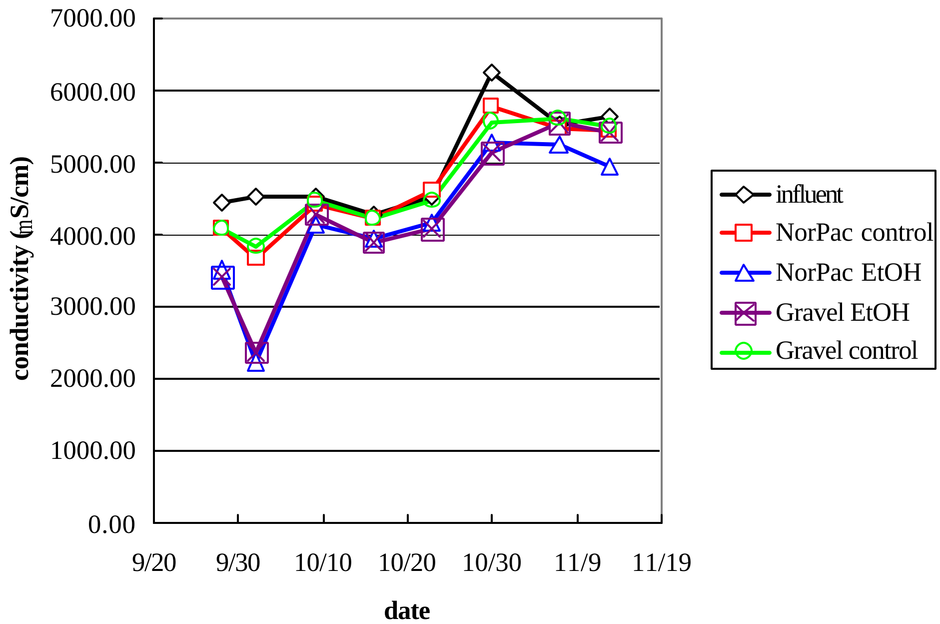

Figure 5. Specific conductivity measured in the influent and effluent for each column during the treatability study.

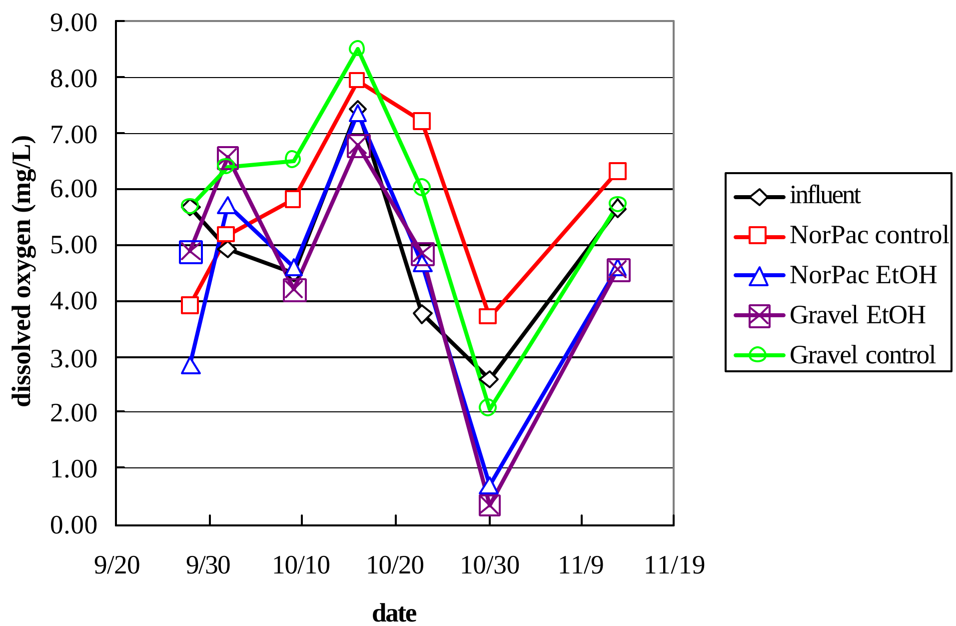

Figure 6. Dissolved oxygen concentration measured in the influent and effluent of each reactor over time during the treatability study.

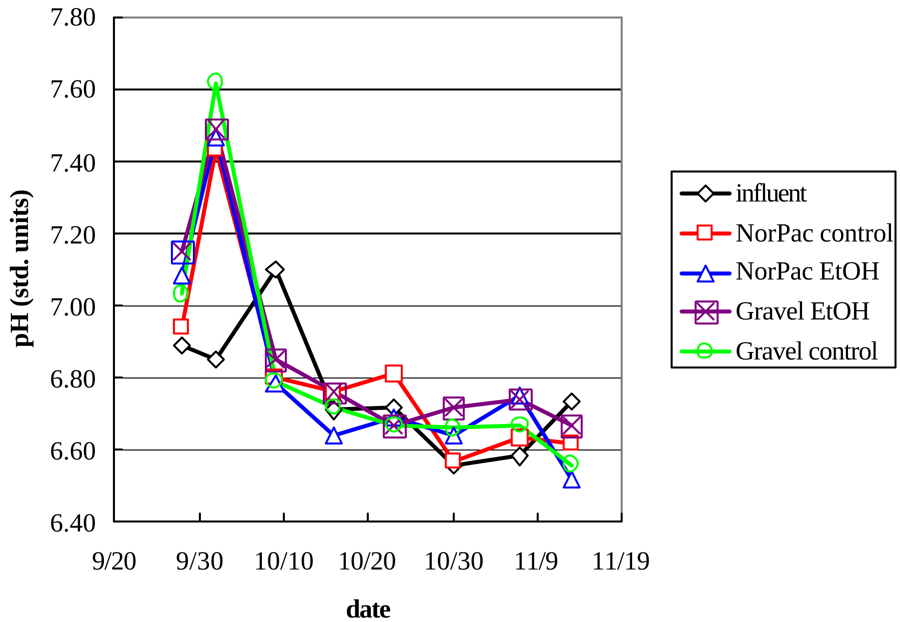

Figure 7. pH measured in the influent and effluent of each reactor over time during the treatability study.

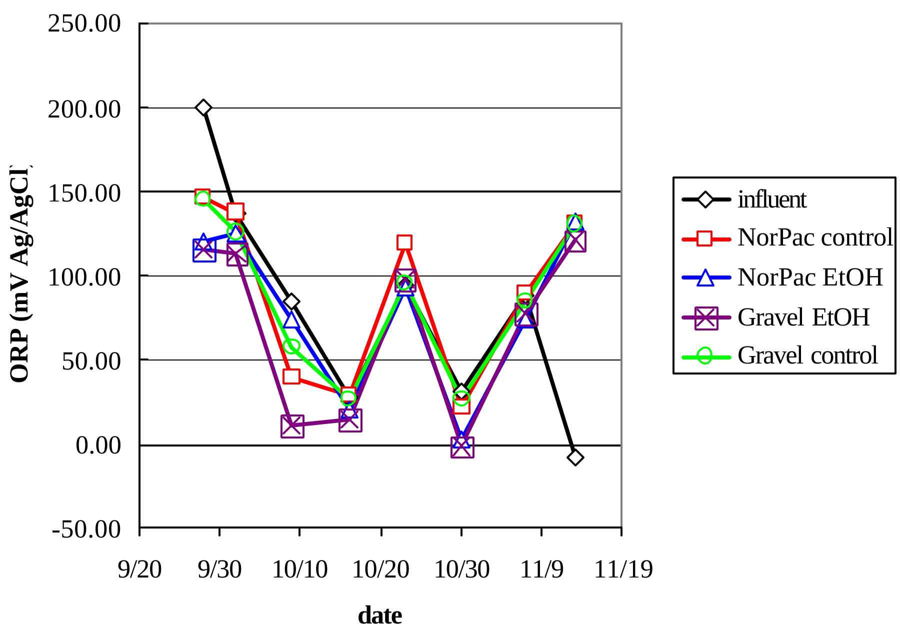

Figure 8. Oxidation-reduction potentials measured in the influent and effluent of each reactor over time during the treatability study.

Summary

Measured parameters do not indicate that establishment of a denitrifying bacteria population occurred in this study. From this, an evaluation of ethanol addition and substrate media would not be practical. The lack of nitrate reduction in the test columns could have been the result of several factors including:

1. Insufficient retention time in the reactors due to hydraulic short circuiting;
2. Inadequate temperature regulation in the test reactors inhibiting development of microbial communities;
3. Inadequate concentration of macro and micro nutrients necessary for the microbial consortiums to develop and sustain nitrate reducing conditions; and
4. Experimental duration too short for establishment of denitrifying bacteria population.

Although data generated are not sufficient to evaluate ethanol addition and substrate media, knowledge was obtained from this study that will be beneficial to future studies. In particular, future studies should incorporate the following:

1. Inclusion of an initial batch study to provide data for design parameters;
2. Greater time allotment (i.e., on the order of several months) for establishment of microbial population;
3. Improved temperature control in the test reactors;
4. Improved hydraulic retention in the reactors; this could include improved reactor design and/or conducting tracer tests prior to deployment, verifying hydraulic retention times are met; and
5. Characterization of site water for availability of micronutrients.